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Soybean Cultivation and Research

in

The People's Republic of China

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The People's Republic of China

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SOYBEAN CULTIVATION AND RESEARCH IN THE PEOPLE'S REPUBLIC OF CHINA /+c

by

... [et al.]. --

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All comments, opinions, and recommendations in this report are those of the team members and not necessarily those of the sponsoring institutions. "The study tour was jointly sponsored by the USDA Office of International Cooperation and Development and the Ministry of Agriculture of the People's Republic of China."

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INTRODUCTION

A team of U.S. soybean scientists visited the People's Republic of China in August and September 1981, with the objectives of promoting interactions of soybean germplasm information and developing groundwork for the initiation of germplasm exchange, collecting biological control agents of insect pests for transport to the U.S., and discussing the exchange of other biological control agents, exploring possibilities of germplasm resistant to insects, viruses, and soybean cyst nematodes, and looking for potential biocontrol agents for soybean cyst nematodes.

This report is a summary of the observations of the team members. It consists of four papers authored by the team members: "Soybean Cyst Nematodes" by Robert D. Riggs, "Soybean Diseases and Dodder" by Robert M. Goodman, "Soybean Germplasm" by Reid G. Palmer and Keith J. Smith, and "Soybean Entomology and Biological Control" by Marcos Kogan and Samuel G. Turnipseed.

SOYBEAN CYST NEMATODE (SCN)

Robert D. Riggs, University of Arizona

Soybean cyst nematode (SCN) was found in the northeastern provinces of the People's Republic of China. In the Heilongjiang Province, SCN was the No. 1 disease problem on soybeans, but it was serious only in an area in the western part of the province. The cyst was between generations at the time of our visit; we did not find it in the fields around Harbin.

The staff of the Heilongjiang Academy of Agricultural Sciences were very interested in methods for separating races and in varieties with resistance. They indicated that some U.S. resistant varieties they had received were good hosts of their nematodes.

The Jilin, Liaoning, and Shandong Provinces had no one working on nematodes. SCN was the No. 3 disease on soybeans in Liaoning and Shandong, but they were not concerned about it. Fields with 75 percent damage and others where the crop was completely destroyed were the exception, and SCN was not a problem because of the rotation of wheat/corn/soybean or millet/corn/soybean in a 3-year cycle.

We were able to find mature females in almost every field we visited in these three provinces. At Shenyang, the beans appeared to have suffered some damage. Shenyang and Jinan had a perfect situation to check many of their native collections

for resistance to SCN. The collections were planted in SCN-infested fields and all they needed to do was go through and dig a few roots of each one, not even whole plants. However, there was no one to do this type of work and interest in doing it was not apparent.

As long as the Chinese follow their present rotation program, they probably will not have serious problems with SCN. They probably will follow this program as long as the ratio of soybean to other crops remains as it is. If they should shift to a higher proportion of soybeans and do not stay with the rotation program, they could have serious problems. The Chinese have not checked SCN resistance in their germplasm, and we did not have the opportunity to do any checking in variety tests. We will continue to work on possible biological control agents with cyst collections which we brought back from the People's Republic of China.

SOYBEAN DISEASES AND DODDER

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SOYBEAN DISEASES AND DODDER

Robert M. Goodman, University of Illinois

Introduction

Reports by previous travelers from U.S. agricultural institutions indicated that, in soybeans, virus diseases were considered among the most important disease problems in the People's Republic of China. This assessment was undoubtedly a major reason for including virology in the disciplinary specialities represented on the 1981 soybean delegation. However, the trip was not organized to provide a comprehensive view of soybean virology research or knowledge in the colleges, universities, institutes, and academies of the People's Republic of China. Therefore, this report is an attempt to assess the quality and significance of the virus research we saw, but is not necessarily an exhaustive or even nearly complete picture of soybean virology in the People's Republic of China. The views expressed are our best judgment about what we saw and were told.

To a surprising degree, people in virology, entomology, and plant breeding in the People's Republic of China do not work very closely together, even if they are in the same institution. For example, at Harbin, which is a major soybean-growing area, breeding work is currently done in the Provincial Academy of Agricultural Sciences, while the virology work is done in the Northeast Agricultural College. It is not clear

how these are related. At Jilin, both virology and breeding projects are at the Provincial Academy, and there seems to be a reasonable connection between them. In Liaoning Province, the breeders and pathologists at Tieling, working in the same institute, appear to have little to do with one another.

Personnel

Very few of the well-trained plant virologists in the People's Republic of China work on soybean viruses. We met with fewer than a dozen scientists who were doing even the most rudimentary virology in this crop. It will be some time before the People's Republic of China will have the trained scientific personnel working in soybean virology to carry on a fully mutual and reciprocal scientific relationship with developed world institutions where agricultural virology in general, and soybean virology in particular, is done. There are a few excellent scientists working in plant virology in the People's Republic of China. We met with members of the staff of the Institute of Mirobiology, Academia Sinica, Beijing; the Institute of Biochemistry, Academia Sinica, Shanghai; and at Fudan University, Shanghai. With responsibility for more basic aspects of virus research, these institutions also show a real awareness of the agricultural needs and importance of work in this area, and their science is first class. We had insufficient time to learn how research by universities or Academia Sinica laboatories (for example, on diagnostic methods) gets translated into practice in the agricultural research institutions.

Virus Occurrence

Soybean mosaic virus (SMV) is the only virus shown with reasonable scientific evidence to occur in soybeans in the People's Republic of China. In the view of the scientists we met, SMV is the only soybean virus known in the country. Bud blight disease and soybean dwarf disease have both been reported in the People's Republic of China, but proof of the occurrence of tobacco ringspot (TRSV) and soybean dwarf viruses in the People's Republic of China has not been shown.

We saw virus-like disease symptoms only once that could not be easily attributed to SMV. That occasion was in a germplasm planting at Jinan and the symptoms were like those described in Japan for soybean dwarf. We frequently saw top necrosis and at Jinan also purple pod and stem lesions associated elsewhere with bud blight disease caused by TRSV. But it is impossible to tell from field observations alone if TRSV was the cause or if it was due to SMV in combination with particular soybean genotypes in which top necrosis is also known to occur.

The few virus identification studies we heard about were based entirely on host range evaluations and, in two cases, electron micrographs showing flexuous rod-shaped particles resembling those of SMV. Limited serology work has been done at the Northeast Agricultural College, Harbin, with purified virus an antiserum produced there, but elsewhere no serology or other indexing techniques were in use on soybean viruses; only at Harbin and Gongzhuling was sap inoculation for

field experiments being used. Thus, the evidence on soybean viruses, their identification, distribution, and importance rests on a very thin layer of scientific research at a few institutions.

There is little doubt that soybean virus diseases are of importance in the People's Republic of China. However, there is no good information available, even for a province or a district, of what the loss caused by virus diseases might be. As also in the U.S., the evidence of virus disease symptoms is more prevalent in the South.

Soybean mosaic virus appears to be widespread, both in experimental fields and in production fields. We were frequently given 1 to 2 percent as the incidence in production fields. Nearly 100 percent incidence was noted in some lines growing in germplasm fields at Tieling (Jilin) and at Jinan (Shandong). At Jinan, the incidence of SMV-like symptoms in 14 varieties in the Shandong regional variety trial ranged, by our estimate, from no less than 10 percent to as high as 50 percent. Thus, even in the best material produced by soybean breeding institutions in Shandong, the incidence of SMV is very high. It was impossible to tell whether this was due to seed infestation or spread from the germplasm planting nearby, or both. No records were kept of early-season virus incidence; we saw the trial in late August. There was no evidence of SMV in a similar regional trial for Jilin Province at Gongzhuling.

Everywhere we went, soybean mosaic was among the three most important diseases cited (usually along with powdery mildew and cyst nematode). As best we could judge, this assessment was

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in all cases based on disease incidence, not yield loss or some other measure of economic significance.

In the northeast (Heilongjiang, Jilin, and possibly Liaoning), SMV appears to be a minor problem in terms of economic loss compared, for example, to pod borer, aphids, and possibly stinkbugs and cyst nematode. The incidence of SMV-like symptoms, however, was higher than in comparable soybean-growing areas of the U.S. Further south, in Shandong, the disease incidence appears to be higher. We readily found SMV symptoms and plant-to-plant evidence of reduced pod numbers in production fields in a commune in Dongping County, Shandong. Yield loss assessments, however, are impossible to make based on the information available. Virus incidence in a field near Shanghai was apparently very high (20 to 50 percent) and the symptoms unusually severe.

Epidemiology

Knowledge of soybean virus epidemiology in the People's Republic of China is limited. However, the relationship between seed mottling and virus infection of the mother plant is widely understood. We were not able to judge for ourselves or obtain other reliable information on the incidence of seed mottling, for example, in production seed or seed lots destined for planting. Seed transmission rates were reported as being "typically" 1 to 2 percent in seed lots with some varieties having higher incidences. This value must be accepted cautiously because of the lack of reliable and routinely used virus detection methods in most of the institutions we visited.

The importance of seed transmision to virus spread in the field is also understood. We had almost no opportunity to learn about the seed production and distribution system. It is handled by a seed company in each county which grows or contracts with commune production brigades to grow soybeans for seed use. The system for seed production appears to be such that some degree of control over harvesting from virus-infected seed could be, and perhaps is, practiced.

The inoculum reservoir question is complicated in the People's Republic of China, however, by the occurrence of seed transmission of, and infection by, SMV in the wild soybean, _Glycine soja_. _G. soja_ occurs widely in the vicinity of cultivated soybean fields and occasionally is found growing together with _G. max_, especially in the northeast. We could not form an impression of the incidence of SMV in wild soybeans, but we were told it occurs. At Gongzhuling, Jilin, we saw _G. soja_ growing in experimental plots and some of the lines had a high incidence of what appeared to be symptoms typical of SMV.

There are two distinct populations of aphids associated with soybean in the People's Republic of China. Several species of aphids colonize soybeans, and these constitute an important enough pest problem to have elicited considerable research on chemical and biological control methods (see p. B-20). The colonizing species as given to us included _Aphis glycines_, _A. gossypii_, _A. craccivora_, and _Macrosiphum pisi_ (probably a misidentifi- cation of _Aulocorthium solani_); all are species reported in the world scientific literature to

transmit SMV. We heard at Gonghuling about work showing that A. glycines can transmit SMV experimentally.

Also presumably present in soybean fields in the People's Republic of China, as in the rest of the world, are nonresident or transient Alatae of various species. Essentially no work appears to have been done on the nonresident species or on their role as SMV vectors.

The scientists we talked to appeared to assume that the resident aphid species were the vectors responsible for field spread of the virus, but as far as we could learn, there has been no attempt to experimentally test this assumption. At Gongzhuling we were told that, as a matter of casual observation, control of resident aphids by insecticides prevented spread of SMV. On the other hand, we saw evidence of recent SMV infection in fields in Shandong Province in which there were no resident aphids in sight and no foliar evidence of there having been any present earlier in the season. The question of the vectors responsible for SMV spread in Chinese soybean fields is, in our view, wide open.

Part of the problem with epidemiology and other studies on soybean viruses in the People's Republic of China is that few places have virus detection methodology advanced beyond the stage of looking at symptoms. Few people do host range studies, fewer serology or routine insect transmission work, and few even do sap inoculation trials to look for resistant germplasm or measure spread to nearby healthy plants. They take the presence of resident aphids in the field, along with knowledge

that these species can transmit, as evidence that these species <u>do</u> spread the virus in the field. This may be correct, but it may not be.

Genetic Resistance and Germplasm

People at most institutions we visited were aware of the importance of genetic resistance in the control of soybean virus diseases. However, neither at the provincial nor the national level is there any systematic screening of germplasm for virus resistance. There is apparently no system for recording what information might be available from causal experience.

We heard numerous reports of "virus-resistant" (meaning in all cases, virus-tolerant) improved varieties, especially in Heilongjiang, Jilin, and Liaoning, but there were apparently no controlled tests using sap inoculation or spreader rows and natural transmission to test these materials except at Gongzhuling and possibly Harbin. In the case of Gongzhuling, we saw a field experiment in which 46 lines (including native varieties, *G. soja* accessions, and improved varieties from several places) had been inoculated manually in an unreplicated test using water-diluted inoculum prepared from symptomatic plants elsewhere in the experimental plots. Based on the typical symptomatology in some of the inoculated lines, we assume SMV was present in the inoculum and the inoculation procedure (by brush without abrasive) was more than 90 percent successful. All of the *G. soja* accessions had symptoms. The varieties without symptoms were as follows:

Variety	Plot No.	Comments
Da Bai Mai	13	Local native variety
Lei Dian	14	
Qin Dou 84	15	Local native variety
Wen Feng #5 (1538)	28	Variety from Shandong
Wen Feng #5 (1893)	29	Variety from Shandong

Other interesting test results were with Li Wai Qing (plot No. 11), a green-seeded local native variety which showed severe top necrosis and stunting; and Friendship #2, a variety from Anhui Province, in which approximately half of the plants had severe top necrosis and the others were symptomless. The plans for this test included the resistant or immune varieties as parents in crosses with high-yielding, adapted varieties from Jilin Province.

At Harbin there was great interest in SMV strain classification and familiarity with the concept and importance of strains and virulence. The process of selection leading up to developing new varieties may have selected useful sources of field or general resistance that, if properly handled, could be very useful in developing better varieties, both in the People's Republic of China and elsewhere.

Other Diseases

Diseases other than virus and cyst nematode appear to be minor at the present time. We were told that they obtain very high germination rates (95 to 98 percent) in the northeast, even on communes, and we saw little evidence of other foliar or soilborne pathogens.

Among the pathogens mentioned by various scientists as being recognized in soybeans were the following:

Cercospora kikuchii

Cercospora sojina

Pseudomonas phaseolicola

Macrophomina phaseolina

Peronospora manchurica

Septoria glycines

We found symptoms of pod and stem blight (*Diaporthe phaseolicola*) in the field at Shenyang, Liaoning. This pathogen is recorded in the literature as occurring in the People's Republic of China.

With the exception of *Peronospora*, all of the above pathogens were considered of minor or no importance by the scientists we met. *Peronospora* was often given as one of the three most important disease agents in soybeans. However, this assessment was based on incidence, not losses. In our view, *Peronospora* is probably also of minor importance, certainly in the fields we saw. Rust may be important and perhaps even in places unrecognized. The absence of any plant pathologist among those we met with at Jinan and Shandong made it impossible for us to learn any more about the soybean rust situation in the People's Republic of China.

Dodder

Reports from previous visits to the People's Republic of China by U.S. soybean scientists had not prepared us for the importance of dodder infestations of soybeans in China. Dodder (*Cuscuta australis* and *C. chinensis* are the most important species) occurs widely in the Yellow River (Huang He) Valley. We found it as far north as Heilongjiang in production fields of the Xiangfang Experimental Farm near Harbin. Mention was made of a Japanese species also occurring on soybeans in China, but we did not get the species name.

Dodder is a microscopic parasitic plant that, like some plant pathogenic fungi, send haustoria-like structures into the plant and, unlike the fungi, establishes phloem-to-phloem conncections between plants. *C. australis*, which seems to be the most prevalent, forms very tightly helical stems around the stem and petiole of the soybean plant and by late August is flowering profusely. The seeds mature about 90 days after germination; they remain on the plant and can be harvested along with the later-maturing soybeans, or they drop into the soil where, in Shandong Province, they remain viable up to 5 years. The seeds are smaller than typical commercial soybean seeds, but are in the size range of smaller-seeded soybeans.

Dodder is a noxious pest with the potential to do serious damage to soybean production. According to Chinese scientists (who were not weed or herbicide specialists) we talked to, there are no suitably specific chemicals available for dodder control or eradication.

So far as we are aware, there are no dodder species in the U.S. that infest soybeans naturally, although there are some that grow on leguminous weeds and clover species. One of us has attempted to experimentally grow dodder on soybeans (using other species in the Illinois Plant Virus Seed Collection), but without success.

Dodder infestations in China are most widespread, according to information received on this trip, in more southern areas. Approximately 1600 ha were infested in Dongping County of Shandong Province in 1981. Yield losses were estimated at 10 to 20 percent in these areas, with some cases of up to 40 percent loss. Even with control (see below), some yield loss results, but successful intervention with control measures prevents spread and further infestation and also prevents seed maturation.

Soybean dodder species, according to our hosts, did not infect other species. We saw dodder (species unknown, but it looked rather like *C. australis*) only one other place, at Linyang temple in Shandong Province where in one case it was growing on a *Chrysanthemum* sp. and in another case on a *Phaseolus* sp. *C. australis* was reported to germinate on cotton but not to develop further.

Control of dodder in soybeans is by several methods. In many areas, farmers weed it out, pulling the soybeans along with the dodder. Crop rotation with a nonhost, even for 1 year, was reported to reduce losses in the following soybean crop. Careful sieving of seeds to remove the smaller dodder seeds also is used. Deep ploughing to bury seeds is also practiced.

In 1963, scientists in Shandong Province isolated *Colletotrichum gleosporoides* from soybean dodder and research since that time has led to a biological control method that is used on a small portion of infested acreage each year, sometimes (including one we saw in Dongping County) with success. The fungus, called Lu Bao No. 1, is grown on agar medium (details not available), and when it is freshly sporulating, is placed in a cloth bag, dipped in water (at a rate of 0.5 kg culture material to 10 kg water), and squeezed to give a spore concentration of about 2×10^7 per ml. This suspension is then sprayed onto the infested plants, usually after fields have been scouted and infested areas marked with bamboo poles.

For best results, spraying is done between 4:00 and 5:00 P.M. on days in which the humidity is high. If the weather is right and the treatment is applied in late July to early August, the dodder begins to die in about 3 days and complete control is obtained about 10 days after spraying. This is sufficient before seed maturation to prevent dispersal of mature seeds.

Dodder is spreading in the People's Republic of China. Its incidence in Heilongjiang has been noted only in the last 2 years. It is considered there a very serious threat to soybean production and should, in our view, be considered as potentially important in U.S. production.

BRIEF SUMMARY OF VIRUS AND DODDER

RESEARCH AT INSTITUTIONS VISITED

Institute of Genetics, Academia Sinica, Beijing

Work has been underway here since 1960 on virus resistance in soybeans. They have studied seedcoat mottling and concluded that it is caused by soybean mosaic virus (SMV). They have isolated SMV from soybean tissues and see typical (but highly aggregated) potyvirus-like particles. Attempts to purify a virus from soy- beans with symptoms of bud blight yielded a particle of 39 nm. The institute has eight soybean accessions with dominant genes for SMV resistance and two with partial resistance. They have developed 11 varieties for use in the Beijing area. They do not use inoculation trials to evaluate their materials, relying only on natural spread in the field without spreader rows. Seed transmission is commonly 6 to 7 percent in susceptible soybean varieties. They have no immunity to SMV in any of their genetic material.

Institute of Germplasm Resources, Chinese Academy of Agricultural Sciences, Beijing

Little virus work is done in this institute. They reported that in the south of the People's Republic of China, Clark 63 was badly damaged by virus and a seed rot occurred while the seeds were still in the pod.

Institute of Horticultural Research, Heilongjiang Academy of Agricultural Sciences, Harbin

Little or no virus research is done here in soybeans, but there are problems under study in other crops.

Heilongjiang Academy of Agricultural Sciences, Harbin

No soybean virus work is done in this academy. All improved varieties of the Hei Nong series are less troubled by virus diseases than the native varieties they replaced.

Northeast Agricultural College, Harbin

This institution is historically the most important soybean virus research location in the northeast. Professor Zhang continues to work on soybean mosaic virus and is very interested in understanding the characteristics of strains of SMV from different parts of the country. She has some cooperative work underway now with people in Professor Fang's group at Nanjing Agricultural College. Varieties of soybeans from Jilin and Liaoning, when inoculated with SMV isolates from Heilongjiang, often give necrotic reactions. Virus strains in the northeast appear to be more virulent than those common in the south. Professor Zhang has never found SMV in nature in plants other than *Glycine max* or *G. soja*. SMV is the only virus reported with certainty from Chinese soybeans to date.

Xiangfang Experimental Farm, Harbin

Dodder infestation was seen in a Hei Nong 26 production field. No virus work is done here, and little in the way of virus symptoms was apparent in the fields we saw.

Jilin Academy of Agricultural Sciences, Gongzhuling

Professor He is the Deputy Director of the Plant Protection Institute and a capable virologist. He is conducting a screening trial with *G. soja*, native *G. max* varieties, and improved varieties. Much SMV was seen in *G. soja* plantings in the experimental plots. In their work, all the variety of symptoms seen are caused so far by SMV. They have shown that aphids colonizing soybeans can transmit SMV but they have not studied epidemiology or nonresident aphids. In studies on SMV in *G. soja*, they find that the seed transmission rate can be very high (70 percent). The relationship between flowering time, infection, and transmission rate through seeds is just as for *G. max*. This institute has been trying in recent years to coordinate research with other institutions in other places, especially on genetic resistance to viruses.

Liaoning Academy of Agricultural Sciences, Shenyang

SMV incidence in commercial varieties in Liaoning Province is 1 to 6 percent. There is no virus research here, but the Director of the Plant Protection Institute is quite interested in this area.

Shenyang Agricultural College, Shenyang

Some virus resistance during breeding was noted, but no virus research is done here on this crop.

Tieling Agricultural Research Institute, Tieling, (Jilin) Liaoning

Testing for virus resistance is done without inoculation or spreader rows. SMV occurs widely at an incidence of 1 to 2 percent in production fields, with much higher incidence in germplasm and experimental plots.

Shandong Academy of Agricultural Sciences, Jinan

No virus research is done here. There was a very high incidence of SMV symptom in their regional variety trial (all 14 entries) and in the germplasm planting. We suggested they take notes on the germplasm lines since the inoculum pressure was so high. They might find some interesting sources of resistance. It was from discussions here and at a commune in Dongping County that most of what we learned about soybean dodder came.

Shanghai Academy of Agricultural Sciences, Shanghai

No soybean virus research is done here, but some quite good work is underway on other crops, especially vegetables and grains.

Fudan University, Shanghai

No soybean virus research is done here at this time, but Professor Wang, who heads the Biology Department, is very interested, especially in the question of virus strain classification. There is some very excellent basic research on plant viruses done here.

APPENDIX

VIRUS COLLECTIONS IN THE PEOPLE'S REPUBLIC OF CHINA

Date	Place	Institute or Commune	Species (# samples)
Aug. 10	Beijing	Institute of Genetics Academia Sinica	*G. max* (3)
Aug. 11	Miyun County Hebei Province	Shilipu Commune Yanluozhai Production Brigade	*G. max* (6)
	Miyun County Hebei Province	Shilipu Commune Yanluozhai Production Brigade	*G. max* (1)
Aug. 13	Heilongjiang Prov.	Institute of Horticulture Harbin	*G. max* (1) Hei Nong #26
Aug. 14	Heilongjiang Prov.	Academy of Agricultural Sciences, Harbin	*G. max* (1)
Aug. 15	Heilongjiang Prov.	Provincial Experimental Farm	*G. soja* (1)
Aug. 18	Jilin Province Gongzhuling	Academy of Agricultural Sciences	*G. soja* (3)
	Jilin Province Gongzhuling	Academy of Agricultural Sciences (screening trial)	*G. max* (1)
	Jilin Province Gongzhuling	Academy of Agricultural Sciences (breeding trial)	*G. max* (1)
Aug. 26	Liaoning Province Tieling	Tieling Agricultural Research Institute	*G. max* (5)
Aug. 30	Shandong Province Jinan	Shandong Academy of Agricultural Sciences	*G. max* (3)
Aug. 31	Shandong Province	Dongping County Huchu People's Commune	*G. max* (2)

SOYBEAN GERMPLASM

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100 Reid G. Palmer, Agricultural Research Service, USDA

Keith J. Smith, American Soybean Association

Introduction

5 China is the home of the soybean (*Glycine max* L. Merr.). For more than 5000 years, soybeans have been a valuable source of protein and oil for the Chinese people. The soybean we know today is considerably different from the wild soybean (*Glycine soja* Sieb. & Zucc.) which grows like a weed in many parts of the People's Republic of China. Through the natural selection process and controlled breeding, soybeans have become one of the world's most important agricultural crops.

Soybeans were first brought to the United States in the latter half of the 1800's. No real effort was made to collect germplasm in China until the late 1920's to early 1930's when USDA scientist, Dr. J. W. Morse, traveled extensively throughout China collecting the old soybean varieties.

U.S. soybean breeders routinely screen the soybean germplasm collection to locate genetic variability, sources of natural pest resistance, and genetic characteristics that contribute to improved yields. Therefore, it is extremely important to encourage the collection, maintenance, and evaluation of the old soybean cultivars, landraces or varieties that, over the centuries, have developed natural resistance to some of today's soybean problems.

In 1979, two soybean breeders and a soybean pathologist visited the People's Republic of China. They were among the first groups to travel under a special nation-to-nation Scientific Exchange Program. In the fall of 1980, two more soybean breeders visited the People's Republic of China. Very little soybean germplasm was obtained by either group. It was with this background that the 1981 Soybean Germplasm and Biological Control Team was organized. The main objective of the germplasm portion of the team was to promote cooperation between the two nations that would lead to the free exchange of information, scientists, and soybean germplasm.

The urgency of germplasm exchange can be better understood by reviewing recent changes in agriculture of the People's Republic of China. Before 1949, the farms were small and privately owned. Farmers planted the same soybean landraces for years. When the land was organized into large state farms, the trend toward planting improved soybean varieties was started. In 1956, the government asked each province to collect the local varieties. Over 12,000 soybean cultivars were collected. These collections remain at the various provincial academies of agricultural sciences.

Today, the number of cultivars in the various collections were considerably fewer than the number collected in the mid-1950's. There are several reasons for the loss: many were lost during the cultural revolution; others with poor agronomic characteristics or "duplications" were discarded by the researchers; and some were lost due to poor storage conditions

and the lack of experience in handling germplasm. While exact numbers are not known, it is estimated there are probably about 6000 different accessions available in the current collections.

To add further emphasis to the importance of collecting and characterizing this valuable natural resource, the team was told that more than 90 percent of the soybean cultivars grown in the major production areas are improved varieties. These higher yielding varieties, released by the provincial academies, are rapidly replacing the native germplasm sources.

In 1980, the People's Republic of China grew approximately 7.3 million ha (18.0 million acres) of soybeans. The average yield was 1979 kg per ha (16.1 bu per acre). The acreage planted to soybeans has been increasing very slowly (less than 1 percent per year). Soybean yields are low and fairly stable.

In the mid-1970's, intercropping of soybeans with corn or grain sorghum was very popular. In recent years, the trend has been toward solid plantings, which improves soybean yields and decreases corn yields. Soybean production in the northeastern areas of the People's Republic of China is more mechanized, making maximum use of mechanical planters, cultivators, and combines. In most other areas of the People's Republic of China, soybeans are intercropped or planted in small plots or planted as border rows. These soybeans are hand-planted, hoed, and harvested.

The eight provinces of Heilongjiang, Jilin, Liaoning, Hebei, Henan, Shandong, Anhui, and Jiangsu produce about 70 percent of the soybeans in the People's Republic of China. In fact, Heilongjiang, Jilin, and Liaoning provinces produce more

than one-half of the soybeans. These provinces are using considerably more technology in their soybean production systems. The team reviewed soybean breeding programs in most of the major soybean producing provinces.

Soybean Germplasm

Glycine max L. Merr is the cultivated soybean. It is not found in the wild, but only occurs under domestication. The progenitor of *G. max* is believed to be the wild species *Glycine soja*. The wild species is found in the People's Republic of China mostly north of 25° latitude. Extensive collection of *G. soja* began in 1978 and is currently being pursued. The intermediate or semi-wild soybean, sometimes called *Glycine gracilis*, is the result of natural hybridizations between *G. max* and *G. soja*. These hybridizations occur at a low frequency; and after several generations of natural self-pollination, these intermediate forms are stabilized.

Glycine max. Accessions of the cultivated soybean have been characterized for response to certain environments, number of branches per plant, number of pods per plant, number of seeds per pod, pubescence color, pod color, leaflet shape, seed size (from 7 to 50 gm per 100 seeds), plant height, and protein and oil percentage of seeds. The completeness of the characterizations of the accessions varies considerably from institute to institute.

At the Jilin Academy of Agricultural Science, Gongzhuling, one-third of the total collection, or 600 accessions, are grown every year for seed increase. Three-row plots are 2 m long with yield calculated from the middle row, but all three rows are harvested for seed.

Glycine soja. The wild soybean is a twining annual plant widely distributed in Heilongjiang, Jilin, Liaoning, and Shandong Provinces. It has been found by Chinese plant collectors in their recent expeditions to occur further west and south than previously had been thought.

Black-, brown-, a few yellow- and a few green-seeded accesssions have been identified. White-flowered *soja* plants were reported but all accessions have brown pubescence. Several accessions with 80 chromosomes were identified. The white-flowered *soja* plants and the yellow- or green-seeded *soja* plants were found as isolated plants or small grou s of plants. Other traits of these unusual plants were similar to the surrounding *soja* plants. (The *G. soja* collection maintained by the USDA has approximately 600 accessions; all have black or brown seeds, purple flowers, brown pubescence, and, where chromosome number has been determined, have 40 chromosomes.)

The largest number of *G. soja* accessions in the People's Republic of China were collected in the Yellow River area. This is also the area that contains the greatest diversity among the accessions. Characteristics that have been studied include: seed size (0.9 to 9.0 gm per 100 seeds), plant height, number of branches, flower color, and pubescence color. Very

little information is available on protein or oil percentage of seeds. No information has been obtained on fatty acid composition of seeds. *G. soja* is not cultivated but, along the Yellow River, seeds are harvested and used by humans.

At the Xiangfang State Farm near Harbin in Heilongjiang Province, we saw extensive areas of *soja* near ditches and irrigation ponds. Our observations of *soja* plants were: thick, dense areas of plants with strong, twining growth habit; in many areas it was the predominant vegetation, not common in heavily shaded areas; after cutting or grazing, it was not the first vegetation to establish regrowth; large variation in leaflet shape and growth; and very good nodulation.

At the compound area of South Lake Hotel, Changchun, Jilin Province, we saw *G. soja* plants growing among shrubs, along roads, and adjacent to fields of corn. The plants were vigorous twiners and exhibited a wider array of leaflet types than plants found at the Xiangfang State Farm.

The most extensive collection and interest in *G. soja* was at Gongzhuling. An active collecting program was started in 1978 and is still underway. The director of the Germplasm Institute spent 2 months in the mountain regions of Jilin Province collecting *soja* and native varieties of *G. max*. Categorization of their 1000 accessions was started in 1979. In addition to traits previously listed, the *soja* accessions are being evaluated for photoperiod insensitivity. Because of the lack of long-term, cold-storage facilities for seeds, the germplasm collection is grown every 3 years.

Intermediate Types. These types arise from natural hybridizations between native varieties or improved varieties and *G. soja*. These intermediate or semi-wild soybeans were described by Skvortozov in 1927 based on plants found along the Songhua River in Heilongjiang Province.

Intermediate type plants are shorter, more branched, have greater shattering of pods, and small- to medium-sized seeds (less than 12 gm per 100 seeds) that are black, brown, or olive colored. Plants are commonly found as weeds in mung bean fields. In certain marginal production areas, the intermediate types are cultivated and used for animal feed (forage or hay) and for human food. A liquor is made from the seeds. The general belief among the scientists that we visited was that the intermediate types were more tolerant of adverse environmental conditions, diseases, and insects. Through selection by man, these intermediate types may be released as local varieties. These varieties represent an important source of germplasm that is fast disappearing as improved varieties become available.

Hybrids Among the Various Species. Many of the earlier varieties were the result of crosses between intermediate types followed by human selection for higher yielding varieties. These varieties are known as the native varieties. In present plant breeding programs, one parent commonly is a native variety and the other parent, an improved variety.

Interspecific and intergeneric hybridizations were done at the Genetic Institute, Chinese Academy of Sciences, Beijing.

Reciprocal crosses between _G. max_ and semi-wild types have been made and are being used in genetic studies.

Also at the Genetic Institute, approximately 900 reciprocal crosses between _G. max_ and the perennial _Glycine_ species have been made. The few shriveled seeds obtained were placed on embryo culture medium, but the small seedlings died.

Over 20 years ago, _G. max_ x _G. soja_ crosses were made and progeny advanced to the F_4 generation at the Northeast Agricultural College, Harbin. This breeding material was lost and only recently breeders and geneticists at Gongzhuling have repeated these crosses. The main purpose for using _soja_ seems to be as a source of genes for higher percentage of seed protein. Oil content of seeds is also being monitored because of the inverse relationship between oil and protein contents of seeds. Secondarily, _soja_ may be a source of genes for other traits.

At Harbin the team saw F_1 plants from _G. max_ x _G. soja_ crosses that had considerable ovule abortion. We reasoned that this sterility was caused by a chromosome translocation. At Gongzhuling we asked about partial sterility of the F_1 hybrids between _G. max_ x _G. soja_, but the scientists had not checked. Our impression was that they did not think partial sterility was present.

At the South Lake Hotel, Changchun, Jilin Province, we observed two intermediate types among a population of _G. soja_ growing adjacent to a corn field. These plants had the phenotype of _G. gracilis_ accessions that are in the USDA Soybean Germplam Collection.

Scientists at Harbin and Gongzhuling indicated that a small percentage of semi-wild types occur, both among _G. max_ plantings and among _G. soja_ populations.

At the Xiangfang State Farm, we saw _G. soja_ plants that were twined around _G. max_ in a production field. Even if natural outcrossing is low, the opportunity exists for natural outcrossing.

G. max and _G. soja_ are found together throughout the People's Republic of China. This is true even in the western and southern areas where soybean production is limited.

Other Species. The perennial species _G. tabacina_ and _G. tomentella_ have been found south of 25° latitude. We were not given any additional information on the perennial species.

Breeding Objectives

The main emphasis in the soybean programs reviewed was for high yielding varieties. Traits selected included early maturity, greater pod height, resistance to shattering and lodging, drought or cold tolerance and insect/disease resistance.

There was no systematic mass screening of the germplasm for specific traits, nor were efforts made to inoculate plants or create environments where evaluation could be made. (The common practice was to make the crosses and to observe the results in natural environments.)

More institutions had varieties or breeding lines that were partially resistant to the soybean pod borer. Emphasis was on increasing the level of resistance in their cultivars. The only known resistance source is a Japanese cultivar.

Narrow-leaflet cultivars were favored in Heilongjiang and Jilin Provinces. Both academies were conducting single-leaf photosynthesis studies, under field conditions, comparing leaf types. They claimed better light penetration in the narrow leaf varieties. The team saw no data on differences in photosynthesis rate between the two leaf types.

Most academies were emphasizing soybean quality characteristics in their breeding programs. They were measuring both oil and protein content. Protein was measured by the Kjeldahl method or by use of a Neotec near-infrared reflectance instrument. The academies were not measuring fatty acid composition of the seed.

At the Genetics Institute, Chinese Academy of Sciences (Beijing), geneticists have postulated that there are eight dominant and two partially dominant genes for soybean mosaic virus (SMV) resistance. These results are from 11 hybrid combinations.

Some germplasm testing for viral resistance was being done at Jilin Academy of Agricultural Sciences. A total of 46 soybean lines were inoculated and disease incidences were being evaluated.

Most of the improved varieties had light hilum and yellow seedcoats. They indicated that dark hilums found in many U.S. soybean varieties are objectionable to the Chinese.

Breeding Methodology

The Chinese were using several breeding techniques to improve soybean varieties. The pedigree method of plant breeding was the most common method used. Mass selection and backcrossing were mentioned by only one institution. Considerable interest was expressed in single-seed descent and recurrent selection as methods to use in plant breeding. Population improvement via male sterility with recurrent selection is underway at Shenyang Agricultural College.

In the hybridization program, one parent was usually an improved native variety. Germplasm from the U.S. was generally not used due to susceptibility to viral diseases. One Japanese variety was used as a source of resistance (partial) to the soybean pod borer.

Mutation breeding was mentioned frequently and usually referred to radiation treatment rather than chemical mutagenesis. One procedure was to cross two non-radiated parents, grow the F_1 seed, and radiate half of the F_2 seeds. The other half of the F_2 seeds were not radiated and served as the control population.

During the past 20 years, Heilongjiang Academy of Agricultural Sciences (Harbin) has produced 14 improved varieties. One was selected from a native variety, six were from radiation, and seven from hybridization with selection among progenies.

Most academies are using a winter nursery to obtain an extra generation increase during the winter months. With the winter nursery, the soybean breeders felt it probably took 10

years to produce an improved variety. Most of the academies were using the nursery on Hainan Island, Guangdong Province. However, Shandong Academy of Agricultural Sciences was using a winter nursery at a different location in guangdong Province.

Seed Release and Multiplication

Pure seed (breeders' seed) is produced at the academies or agricultural colleges. These seeds may have been the result of selection within native varieties, mutation breeding, or conventional breeding techniques from hybridization.

A preliminary 3-year test, followed by a 2-year commercial test, is the usual procedure for evaluating lines to be considered for release. A selection committee inspects fields during the growing season and meets each year to determine if a variety should be released. A variety must be 10 percent or more above the highest yielding check cultivar in the test to be considered for release.

The number of test locations varied from province to province, but the number of entries per test was usuall 10 to 20 plus appropriate check varieties. The checks were improved high yielding cultivars.

In Jilin Province, the variety test plots consisted of eight rows, 6 m long, and end-trimmed 0.5 m. The middle six rows were hand-harvested for yield. Three to four replications were used. Protein and oil percentages were determined, but we were not told about measurements of additional traits.

Varieties selected for multiplication were grown by the provincial seed farms and sold to communes or state farms. Seeds were purchased each planting season rather than planting seeds harvested the previous year. New varieties were introduced every 3 to 4 years.

Heilongjiang, Jilin, and Liaoning Provinces grow improved varieties on 90 percent or more of their soybean hectarage. Native varietes are grown on the marginal areas. However, in Shandong Province, we were told that only 50 percent of the soybeans planted were improved varieties.

Cultural Practices

Cultural practices studies have not been emphasized in soybean production. While some research has been done with plant populations and row spacings, the studies have not been very extensive. The Chinese seem to use the terms "soybean research" and "soybean breeding" interchangeably.

A large percentage of the soybeans in some provinces are intercropped with corn or sorghum grains. Planting arrangements vary; however, 4-2, 4-4, or 6-6 rows were quite common. Since the Cultural Revolution, more emphasis has been placed on growing soybeans in pure plantings. Generally, corn yields more in an intercropped pattern compared to a pure stand. The opposite effect is true for soybeans.

As we moved from Heilongjiang to Jilin to Liaoning to Shandong Provinces, the team saw less use of pre-emergence grass herbicides and mechanization of land preparation, planting, cultivation, and harvesting. There seemed to be a close relationship between degree of mechanization and intercropping; hand labor and intercropping seemed to be related.

Also, as we moved south, more soybeans were double-cropped, usually after winter wheat. In Shandong Province, 90 percent of the soybeans were planted after winter wheat.

The lack of weed control research by the Chinese was somewhat surprising. Most soybean fields were free of economically damaging weed populations since the fields were cultivated three times and hand-weeded two to three times. We were told that three major U.S. chemical firms are interested in cooperating in some joint herbicide studies.

The Liaoning Academy of Agricultural Sciences (Shenyang) reported increased soybean yields by going to narrower row spacings. They were also studying the timing and method of fertilizer application. Several green manure crops were also being compared.

The planting of soybean variety blends was mentioned, but did not seem to be a common practice. Yield increases were reported for blends over those of either component grown in pure stands.

Crop rotation was practiced extensively and probably was responsible for the lack of cyst nematode damage in soybeans. The farmers had several non-host crops that could be used in the rotation systems.

Soybean Tissue Culture

Only two locations visited were conducting soybean tissue culture studies. Heilongjiang Academy of Agricultural Sciences (Harbin) has been studying soybean anther culture for 3 years. They are using a modified B-5 medium and have been successful in obtaining several small seedlings. The small plants died after reaching a height of a few centimeters. Cytological studies confirmed the plants contained 20 chromosomes.

At the Jilin Academy of Agricultural Sciences (Gongzhuling) studies on regenerating plants from tissue culture have been underway for several years. They have successfully used hypocotyl tissue in culture to obtain 40-chromosome plants. These plants flowered, set seed, and matured. Progeny from these plants has reproduced successfully. The research group indicated they have a low, but predictable, success record in regenerating plants from hypocotyl tissue. Now efforts are being directed at plant regeneration from anther culture. They have been successful in regenerating plants, but all died when reaching a height of 2 to 3 cm.

APPENDIX 1

GERNPLASM COLLECTED BY THE TEAM

Jilin Academy of Agricultural Sciences

Gongzhuling, Jilin Province

	Glycine max	Seed color	Seed size
1.	Li Waiging (Gong Di No. 493)	Green	Large
2.	Heihe Xiao Huangdou	Yellow	Large
3.	Pingding Xiang (Gong Di No. 1106)	Yellow	Medium
4.	Dong Feng Duludou (Gong Di No. 806)	Yellow	Medium
5.	Zaotie Jiaging	Yellow	Medium
6.	Yiuofeng (Gong Di No. 57)	Yellow	Medium
7.	Dahuang Dou (Gong Di No. 101)	Yellow	Medium
8.	Heipiging Yiang (Gong Di No. 552)	Black	Medium
9.	Aidadou	Yellow	Medium
10.	Dalihei (Gong Di No. 504)	Black	Large
11.	Silihuang (Gong Di No. 183)	Yellow	Medium
12.	Fu Shou	Yellow	Large
13.	Zi Hua (Gong Di No. 1172)	Yellow	Large
14.	Cha Mo Shi Dou (Gong Di No. 3)	Brown	Medium
15.	Bai Mei (Gong Di No. 278)	Yellow	Medium
16.	Jilin No. 3	Yellow	Medium
17.	Jilin No. 16	Yellow	Medium
18.	Jui Nong No. 9	Yellow	Large
19.	Sui Nong No. 1	Yellow	Medium
	Glycine soja		
20.	Gong Di 2024	Black	Small
21.	Gong Di 685 Huaide County	Black	Small
22.	Gong Di 2002 Jiutai County	Black	Small
23.	Gong Di 2019 Jiutai County	Black	Small

Heilongjiang Academy of Agricultural Sciences

Harbin, Heilongjiang Province

	Glycine max	Seed color	Seed size
24.	Wu Din Zhu (Five Top Gold)	Yellow	Medium
25.	Tei Jia Shi-Li-Huan	Yellow	Medium
26.	Hei Nong 16	Yellow	Medium
27.	Hei Nong 11	Yellow	Medium
28.	Hei Nong 3	Yellow	Medium
29.	Jilin 3	Yellow	Medium
30.	Hei Nong 26	Yellow	Medium
	Glycine soja		
31.	Yaohe County	Black	Small
32.	Aihui County	Black	Small
33.	Suenke County	Black	Small
34.	Suihue County	Black	Small
35.	Beian County	Black	Small
36.	Shaixian County	Black	Small

Jilin District Agricultural Research Institute

Jilin, Jilin Province

	Glycine max		
37.	Jou Nong 9	Yellow	Medium
38.	Jou Nong 1	Yellow	Medium
39.	Jou Nong 2	Yellow	Medium
40.	Jou Nong 4	Yellow	Medium
41.	Jou Nong 5	Yellow	Medium
42.	Jou Nong 6	Yellow	Medium
43.	Jou Nong 7	Yellow	Medium

Liaoning Academy of Agricultural Sciences
Shenyang, Liaoning Province

	Glycine max		
44.	Liao Nong 9	Yellow	Medium
45.	Liao Nong 1	Yellow	Medium
46.	Tie Feng 18	Yellow	Medium
	Astragalus adsurgens		

Tieling District Agricultural Research Institute
Tieling, Liaoning Province

	Glycine max	Seed color	Seed size
47.	Tie Feng 3	Yellow	Medium
48.	Tie Feng 8	Yellow	Medium
49.	Tie Feng 17	Yellow	Medium
50.	Tie Feng 18	Yellow	Medium
51.	Tie Feng 19	Yellow	Medium

Huchu Commune, Dongping County, Shandong Province

	Glycine max		
52.	Weng Feng 8 (Tai Mountain 1)	Yellow	Medium
	Triticum aestiuum		

Shanghai Academy of Agricultural Sciences, Shanghai

	Glycine max		
53.	Wu Yui Huo	Yellow	Large

APPENDIX 2

SOYBEAN GERMPLASM PRESENTED TO IOWA STATE UNIVERSITY

(Authority given by

Chinese Academy of Agricultural Sciences, Beijing

Glycine max		
Tie Fen 8	Liaoning Province, Tieling	Improved
Tie Fen 9	" " "	Improved
Tie Fen 16	" " "	Improved
Tie Fen 17	" " "	Improved
Tie Fen 18	" " "	Improved
Tie Fen 19	" " "	Improved
Kai Yu 3	Kauyuan County, Liaoning	Improved
Qun Xuan 1	Jilin Province (Youngfendou County)	(native), Found in field of Youngfendou, developed via pedigree method. Parent unknown, was a natural cross.
Hei Nong 26	Heilongjiang Province	Improved
Beijing Hei Dou	Heilongjiang Academy (from Beijing)	maybe *gracilis*
Ji Ti 2	Heilongjiang	Improved
Ji Ti 3	"	Improved
Ji Ti 4	"	Improved
Ji Ti 5	"	Improved
Dan Dou 1	Dandong (a city in Liaoning Province near Korea)	Improved
Dan Dou 2	"	Improved
Dan Dou 3	"	Improved
Kai Yuan Bai Mei	Kaiyuan County	High protein - native, white brow (hilum)
Qi Huang 1	Shandong	Improved
Shi Li Huang	Jilin - Liaoning	4 seeds yellow-native

Tie Jia Qing	Liaoning	Black pod, green seedcoat, native
Jin Dou 33	Jinzhou (city) - Liaoning	Improved
Jin Dou 34	" " "	Improved
Jin Dou 8-14	" " "	Improved
Jin Hun 14	" " "	Improved
Yue Jin 4	" " "	Improved

Glycine gracilis

Hei Mo Shi Dou Gong 205	Gongzhuling	Black seedcoat, soybean for forage
Hei Mo Shi Dou Gong 550	Gongzhuling	Black seedcoat, soybean for forage
Bai Mo Shi Dou Gong 1644	Gongzhuling	White seedcoat, soybean for forage
Cha Mo Shi Dou	Gongzhuling	Brown seedcoat, soybean for forage

Glycine soja

LS-001	Chungtu County, Liaoning
LS-004	Kaiyuan County, Liaoning
LS-005	Tielin County, Liaoning
LS-008	Sinbin County, Liaoning
LS-009	Haichem County, Liaoning

Soybean germplasm fron Nanjing Agricultural College

Glycine soja

81-200001

81-200002

81-200004

81-200014

81-200016

81-200027

Glycine max

133-3	Improved
493-1	Improved
58-161	Improved
1138-2	Improved
Su Xi No. 1	Improved

Soybean Germplasm from Gongzhuling

Jilin Academy of Agricultural Sciences

Glycine max

Weng Feng #1538	Improved
Weng Feng #1893	Improved
Li Wai Qing	Native
Raiden (Lei Dian)	Originally from Japan

APPENDIX 3

Rhizobium japonicum SAMPLES COLLECTED BY THE TEAM

Sample	Genus	Variety	Location	Date
1	Glycine max		Shilipu production brigade, Shilipu Commune, Miyun Co. Hebei Province	8/11/81
2	Glycine max		Yanluozhai production brigade, Shilipu Commune, Miyun Co. Hebei Province	8/11/81
3	Glycine max	Hei Nong 26	Inst. of Horticulture Prov. Academy Agri. Sci. Harbin, Heilongjiang Prov.	8/13/81
4	Glycine max	Hei Nong 26	Soybean Research Inst. Prov. Acad. Agri. Sci. Harbin, Heilongjiang Prov.	8/14/81
5	Glycine max	Wild species	Xiangfang State Farm Harbin, Heilongjiang Prov.	8/15/81
6	Glycine max	Hei Nong 26	Xiangfang State Farm Harbin, Heilongjiang Prov.	8/15/81
7	Glycine max	Jilin 3	Soybean Institute Jilin Academy Agri. Sci. Gongzhuling, Jilin Prov.	8/18/81
8	Glycine max	Jilin 13	Soybean Institute Jilin Academy Agri. Sci. Gongzhuling, Jilin Prov.	8/18/81
9	Glycine max	Jui Nong 9	Wulagie Commune Yuyonggi County Jilin Province	8/19/81
10	Glycine max	Jui Nong 9	Jilin District Agr. Res Inst., Jilin Jilin Province	8/20/81
11	Glycine soja	Wild species	Jilin Agri. College Changchun, Jilin Prov.	8/23/81
12	Glycine max	Chang Nong 2	Jilin Agri. College Changchun, Jilin Prov.	8/23/81

Sample	Genus	Variety	Location	Date
13	*Glycine max*	76-41-38	Liaoning Academy Agri. Sci., Shenyang Liaoning Province	8/25/81
14	*Glycine max*	Tie Feng 18	Tieling Distr. Agri. Res. Inst., Tieling Liaoning Province	8/26/81
15	*Glycine max*		Shandong Academy Agri. Sci., Jinan Shandong Province	8/30/81
16	*Glycine max*		Juchu Commune Dongping County Shandong Province	8/31/81
17	*Glycine max*		Field in apple orchard South Suburb Hotel Jinan, Shandong Prov.	9/01/91

SOYBEAN ENTOMOLOGY AND BIOLOGICAL CONTROL

CONTENTS

SOYBEAN ENTOMOLOGY AND BIOLOGICAL CONTROL

Marcos Kogan, University of Illinois
Samuel G. Turnipseed, Edisto Experiment Station

Introduction

Interest in the status of soybean insect pests in the People's Republic of China stems from the fact that these pests are part of a fauna that has coevolved with the native soybeans and it is, therefore, well adapted to the crop. It is hypothesized that this coevolutionary process has probably preserved mutations that increased the overall levels of resistance of soybeans to pests. It has also led to existence of several host-specific pests, such as the soybean pod borer and the soybean aphid which are considered very serious pests in China. Finally, the complement of natural enemies of many soybean arthropods would also be well adapted to control those pests. Indirect evidence to that is the apparently minor importance ascribed by Chinese entomologists to stink bugs and to defoliating noctuid larvae that are among the most serious pests of soybeans in the United States. China is therefore the most likely source of (a) new germplasm potentially resistant to several insect pests, (b) natural enemies potentially useful elsewhere as biological control agents, and (c) information on the host specific pod borers and aphids that are a potential threat to other soybean producing regions of the world. We were vitally interested in these three aspects.

Soybean Entomology Research in the People's Republic of China

Relatively little new basic research is being conducted on soybean insects in the provinces visited. In each location, to discern what was original research or reports from the literature was difficult. In certain instances the latter was obviously the case, and the information had been available for over 20 years. The level of entomological research in the various provinces seems to be rather uneven. The following are brief comments on the provincial status of soybean entomology.

Beijing District

None of the institutions visited in Beijing conducted research on soybean insects. Research at the Institute of Zoology of the Academia Sinica and the Institute of Biological Control (Chinese Academy of Agricultural Sciences), however, provides the foundation for much of the applied work that we observed elsewhere.

Heilongjiang Province

Institution: Plant Protection Research Institute, Heilongjiang Academy of Agricultural Sciences.

Soybean pests reported: *Leguminivora glycinivorella*, soybean pod borer; *Aphis glycines*, soybean aphid; white grubs; and root gall midge.

Pests observed in fields: *Monolepta nigrobilineata*; *Dolycoris baccharum*.

Activities reported: There was no indication that basic research in soybean entomology was carried out in the institutions contacted; no surveys of the soybean insect fauna and their natural enemies were mentioned. Control measures are based on population and life history studies that apparently exist in the published literature. Emphasis is placed on the pod borer which may cause 5 to 15 percent damage. Attempts have been made to use *Trichogramma* spp. releases for control of pod borer eggs, and *Beauveria bassiana* for control of larvae in the soil. Resistance to pod borer is considered in breeding programs using lines selected in Jilin Province as sources of resistance. Special mention was made of the variety 'Tie Jia 3' for its properties of resistance.

Comments: We were informed that there is soybean entomology research at the Northeast Agricultural College, but we did not meet the entomologists. Indication that more study is being conducted in this area than that presented to us is evidenced by the publication of a book on soybean pests that was given to us in Beijing. This book was edited by specialists at Harbin. The soybean pod borer control program seems to be effective and emphasis on breeding for resistance is a logical option.

Jilin Province

Institutions: Plant Protection Research Intitute, Jilin Academy of Agricultural Sciences at Gonzhuling; Jilin Agricultural College at Changchun.

Soybean pests reported: Leguminivora glycinivorella, Aphis glycines, Epicauta chinensis (in the western districts); Monolepta nigrobilineata, Xilicrophorus monolicus, Heliothis dipsacea, Loxostege sticticallis, and Maladera orientalis.

Pests observed in fields: (In addition to most pests listed above): Sylepta ruralis and Plusia agnata.

Activities reported: Aphis glycines and Macrosiphum pisi are the dominant aphid species that colonize soybeans. The biology of the soybean aphid has been studied in detail in the late 1950's by Wang Cenglun and others. Results of these studies were published in 1961 in Acta Entomologica Sinica. Detailed reports on the soybean pod borer were presented. A breeding program for resistance to pod borers was carried out between 1961 and 1963. This program has been resumed since 1979. In Gongzhuling, screening in the field is done under a large field cage (covering 8 x 30 m). The best accessions observed in the field are planted in this cage and pod borer moths are collected in fields and released inside the cage at a rate of about 5 moths per square meter. Evaluation is based on percent damaged seeds.

Comments: Emphasis of the biological control program is on the mass production of Trichogramma for control of European corn borer. Except for the active screening program for pod borer resistance, there is little indication that new biological information on soybean insect pests is being gathered. In Gongzhuling we met probably the most enthusiastic group of entomologists with interests in soybean research, even

though most of them had responsibilities in other areas or crops and devoted little time to soybean research. Some of these areas were: armyworm research, resistance to corn borer, microbial control, etc. However, there is a good potential for cooperative programs with the group of entomologists at the Plant Protection Institute. Much of the information in the summaries of the biology and control of the soybean aphid and pod borers (presented in a later section) is based on reports of scientists from this institute.

Liaoning Province

Institutions: Plant Protection Research Institute, Liaoning Academy of Agricultural Sciences at Shenyang; Insect Laboraory, Tieling Agricultural Research Institute; Shenyang Agricultural College.

Soybean pests reported: *Aphis glycines*, *Leguminivora glycinivorella*, *Etiella zinckenella*, *Heliothis dipsacea*, *Ascotis selenaria*, *Plusia nigrisigna*, *Hedilepta indicata*, *Colias hyale*, *Ilattia octo*, *Japangromyza tristella*, *Melanagromyza sojae*, *Monolepta nigrobilineata*, *M. quadriguttata*, *Xylinophorus mogolicus*, *Opatrum sabaratum*, *Phyllotreta vittata*, *Maladera orientalis*, *Anomala mongolica*, *Dolycoris baccharum*, *Tetranychus cinnabarinus*.

Soybean pests observed: Many of the above species with the predominance of *Dolycoris baccharum* and noctuid larvae.

Activities reported: The long list of soybean pests reported from this province reflects the result of extensive surveys conducted in recent years, particularly by entomologists at Tieling. At Shenyang, personnel of the Plant Protection Institute are mostly concerned with armyworms on corn, sorghum and wheat, European corn borer, and fruit tree moths. In this institute, the only biocontrol reseasrch for soybean pests has been a release of *Trichogramma dendrolinae* for control of pod borer eggs. Results were said to be good, although they could not recover parasitized eggs from the fields. Entomologists at Tieling have conducted extensive surveys for natural enemies of the soybean aphid. They concluded that, although the coccinellid *Harmonia axyridis* was the dominant species in the hilly areas and *Chrysopa* spp. in the plains, control of the aphid depended in part on the presence of a complex of natural enemies. Their main concern in the program is in the conservation of these natural enemies by avoiding use of broad spectrum insecticides. An attempt to use strip applications of Rogor (0.05 kg + 10 kg sand per mu) reportedly produced 90 percent control of treated strips within 24 hrs, and drastic reduction of populations in the non-treated strips 7 to 8 days after the treatment. In this experiment, no yield data were taken. If this experiment can be duplicated and yields taken, the strip-treatment technique may provide a very good option for integrated control programs for soybean pests in the People's Republic of China.

[illegible] The long list of [illegible]

[illegible] upon the [illegible]

in recent years, particularly by [illegible]

heavily [illegible] of the first [illegible]

usually connected with [illegible] corn, [illegible]

[illegible] are little [illegible] by this

institute [illegible]

been a [illegible] of [illegible] for control of [illegible]

their eggs [illegible] were said to be good, although they [illegible]

not recover parasitized eggs [illegible]. Entomologists [illegible]

fields have conducted [illegible] surveys for natural [illegible]

[illegible]. They concluded that although the

[illegible] was the dominant species [illegible]

[illegible] in the plains, [illegible]

[illegible] in part on the presence of a complex [illegible]

[illegible] [illegible]

[illegible] of crops [illegible]

[illegible]

[illegible] reportedly [illegible] percent

[illegible] and [illegible]

[illegible] days after the

[illegible] were taken. [illegible]

[illegible]

Comments: The long list of soybean pests provided by entomologists in this province reflects a greater awareness of field conditions than that detected among the technicians in Heilongjiang or Jilin. However, most of those pests are secondary and do not require insecticide treatments. Insecticides are used for control of the soil pests, particularly white grubs, and for soybean aphids, and occasionally for spider mites. On the other hand, Chinese farmers seem to have a tendency to spray unnecessarily; thus development by provincial technicians of integrated control programs may help prevent outbreaks of these secondary pests that can result from sprays of non-selective insecticides.

There is a large group of entomologists in the Department of Plant Protection of the Shenyang Agricultural College. Some of them are doing research related to soybeans. The group also has experts in the taxonomy of Scarabaeidae and Acari (Phytoseidae and Tetranychidae). Such a strong entomological contingent adjacent to the Academy of Agricultural Sciences should provide the opportunity for ample interaction. We are uncertain, however, whether there is active cooperation in soybean research among the two groups.

At the experimental grounds of the Academy of Agricultural Sciences, we witnessed the heaviest stink bug infestation of our tour of Northeastern China. The dominant species was *Dolycoris baccharum*. We measured populations of the order of 15 to 18 per meter of row. In the United States we consider that three stink bugs (of different species with apparently similar habits) per meter of row may cause economic loss. We

have suggested that efforts be made to initiate a program of study of the occurrence, seasonal abundance, and economic impact of this stink bug in the northeastern provinces. We also offered to provide stink bug egg parasites collected in Australia, Japan, Thailand, and the United States for use in biological control programs. Of particular concern was the presence of this stink bugs in variety trials since severe yield effects (estimated at 30 percent loss) probably resulted from their attack, this influencing the evaluation of lines.

Shandong Province

Institutions: Shandong Agricultural Biological Control Station; Plant Protection Institute, Shandong Academy of Agricultural Sciences.

Soybean pests reported: *Aphis glycines*, *A. crassivora*, *Myzus persicae*, *Etiella zinckenella*, *Leguminivora glycinivorella*, *Plusia egnata*, *Ilattia octo*, *Mocis undata*, *Autographa nigrisigna*, *Ascotis selenaria*, *Hypera rostrilis*, *H. taenialoides*, *Melanagromyza sojae*, *Holotrichia obliqua*, and *Anomala corpulenta*.

Soybean pests observed: Several species of Noctuidae, including Plusiinae and Pentatomidae (gen. sp.?).

Activities reported: Extensive surveys have yielded 75 species of phytophagous insects, in 8 orders of 29 families. The Biological Control Station has collected 100,000 specimens of natural enemies during a 3-year survey of various ecosystems. These included 653 species, in 100 families and 2 classes. The insects represented 486 species in 73 families and 10 orders;

the spiders icluded 86 species, in 16 families and 2 orders. A list of the natural enemies of the most important soybean pests has been provided by the Station's Director, and is included in Appendix 1 (p. B-71). In addition, 25 bacterial and fungal diseases were detected. The most abundant natural enemies were spiders. According to Chinese specialists, natural enemies of insects are more abundant in soybean than in other crop because fewer insecticides are used during the early stages of growth of the crop. This situation is very favorable for development of integrated pest control programs. Protection of natural enemies is the main objective in the program.

In this province we heard for the first time in the People's Republic of China, a full season scheme for control of soybean insect pests:

a. During the seedling stage insecticides are used to control white grubs and stem flies; seed treatments with Phoxim (an organic phosphate developed by A. G. Bayer of Germany) or soil insecticide (Furadan and others) applications are used.

b. Early season (early to mid-July) pests on summer soybeans are controlled by spraying Rogor (dimethoate), malathion, or Sumithion. Sprays are made as early as possible to allow buildup of natural enemies. Coccinellids, Chrysopa, and predaceous Diptera were reported to increase rapdily 10 days after spraying.

c. During flowering and pod-set stages, the targets are 2nd generation leaf caterpillars, pod borers, and stem flies. Chemicals are applied according to a threshold of 50 caterpillars per 100 plants. Chemicals used are Dipterex, Rogor, or Sumithion.

A nuclear polyhedrosis virus (NPV) strain from Russia produced 89.8 percent mortality of <u>Plusia</u> sp. in laboratory studies using a formulation containing 2×10^9 polyhedra per ml. In the field, control was of the order of 72 percent. Mortality occurred 8 days after application. Application of this work was being tested at the Hui Thien District Research Institute.

<u>Comments</u>: In fields of the compound where we stayed (Southern Suburb Hotel) and in those of the Huchu Commune, Dongping County, we observed the most intense populations of lepidopterous defoliators. In one field of the commune, we collected an average of five caterpillars per meter of row. Defoliation, however, was not observed to reach damaging levels.

The surveys and programs that were described reflect a solid entomological foundation. It would be extremely useful to obtain copies of the lists of species surveyed as soon as they are available.

<u>Shanghai District</u>

There is no research on soybean entomology in Shanghai.

MAJOR PESTS OF SOYBEANS IN NORTHEASTERN CHINA

We received most detailed reports on the biology and control of the pod borer, Leguminivora glycinivorella, and of the soybean aphid, Aphis glycines. More sketchy comments were made on white grubs and on leaf-feeding Coleoptera and Lepidoptera. This information is summarized in this section.

The Soybean Pod Borer

The soybean pod borer, L. glycinivorella, was reported as the No. 1 or No. 2 pest of soybeans in all provinces that we visited. This pest has been well studied in the 1950's and new control methods are being developed. Major emphasis is placed on host plant resistance. In the more southern provinces, Etiella zinckenella, the lima bean pod borer, is also frequently mentioned. The damage caused by pod borers in untreated fields has averaged 20 percent, measured by the number of injured seeds in randomly sampled batches of seed; higher records of 40 to 50 percent were not uncommon. L. glycinivorella was recorded from 13 provinces and two autonomous regions in the People's Republic of China.

Biology: There is one generation per year. Mature larvae drop to the soil where they overwinter within cocoons, about 3 cm deep below the soil surface. Larvae and paupae spend about 10 months in the soil. Adults emerge in mid-July and fly to soybean fields. They are not strong flyers and usually do not disperse too far from the area where they emerged. Adult

populations peak between August 10th and 15th (in Jilin Province) and females lay single, fan-like eggs on soybean pods. Optimal conditions for adult breeding are 20 to 25° C and 90 to 100 percent RH (relative humidity). Larvae in the soil are very susceptible to low temperatures. The host range is limited to *Glycine max*, *G. soja*, and the leguminous shrub, *Sophora florescens*.

Biological control: The main natural enemies are the larval parasites: *Pristomerus chinensis* and *Phaneroloma planifrons*. There is also a mermithid nematode on record. Releases of *Trichogramma dendrolimi* have been tested for control of eggs and the fungus *Beauverai bassiana* is used to control larvae as they drop to the soil.

Cultural control: Since adults do not disperse too far from sites of emergence, rotation of crops has given good results. Planting of spring wheat and plowing under the stubble soon after harvest is recommended. This practice reportedly achieves about 25 percent increase in larval mortality in the soil. Cultivation during the month of July also achieved similar results. Thus the main cultural control practices are crop rotation, fall plowing, and mid-July cultivation.

Host-plant resistance: Resistance to pod borers is included in most breeding programs in the People's Republic of China. The main source of resistance has been the variety 'Iron pod four-seeded yellow' ('Tie Jiesulihuan') which is found in the background of several of the Jilin series improved varieties. Some of the varieties reportedly with moderate

levels of pod borer resistance are: 'Hei Nong 7', '-16', and '-26' (only at low population levels), 'Jilin 3', and '-16', 'Jui Nong 1', '-4', '-11', and '-13'. This latter series was produced in Jilin as selections from crosses between the native 'Hei Tie Gia' variety and a Japanese pod borer resistant line (early and late maturing glabrous types).

Two mechanisms of resistance have been identified. In 'Tie Jie-sulihuan' the epidermal cells of the pod well are packed more tightly, offering an obstacle for penetration of newly emerged larvae. In the glabrous podded lines, females oviposit mostly on the more hairly petioles and larvae die before they reach the pods.

Chemical control: Economic injury levels are set at 100 adults per 100 meters of row (adults counted by the flushing method), or percent damage in a sample of 100 randomly collected pods.

A complete control program involves (a) planting of a resistant variety, (b) rotating soybeans with wheat and plowing under the wheat stubble soon after harvest, (c) mid-July cultivation of soybeans, (d) release of *Trichogramma* for egg control in August, (e) application of *Beauveria bassiana* spores for control of larvae, and (f) use of DDVP impregnated sorghum stems for control of adults.

The Soybean Aphid

Several species of aphids colonize soybeans in the Orient. These include *Aphis glycines*, *A. craccivora*, *Myzus persicae*, *Macrosiphum pisi*, and *Aulacorthum solani*.

borer resistance are: 'Hai Hong 7', '[illegible]', and [illegible] (at low population levels), 'Taitan 2', and '[illegible]'. 'Hai Hong 11', '[illegible]', '[illegible]', and '[illegible]'. This latter series was produced by Jill as selections from crosses between the [illegible] and the high [illegible] variety and a [illegible] and borer resistant line (nearly [illegible] [illegible] [illegible] [illegible]).

The mechanisms of resistance have been identified. In [illegible] the [illegible] in the [illegible] [illegible] peduncle more rigid, offering [illegible] for penetration of newly emerged larvae. In the [illegible] [illegible], [illegible] oviposit mostly on the [illegible] varieties and larvae [illegible] before they reach the pods.

Chemical control: Economic injury levels [illegible] set at [illegible] adults per [illegible] or [illegible] was [illegible] [illegible] the [illegible] [illegible], or percent damage of [illegible] [illegible] maturity collected pods.

A complete control program involves (1) planting of a [illegible] variety, (2) [illegible] a [illegible] and [illegible] under the [illegible] [illegible] [illegible] [illegible] (6) [illegible] [illegible] [illegible], [illegible] of [illegible] for [illegible] [illegible] [illegible] (5) application of [illegible] [illegible] of [illegible], or (7) use a [illegible] [illegible] control of [illegible].

The most important species in China seems to be _A. glycines_ which reportedly caused up to 50 percent losses in the early 1950's. Aphids had not been a problem up to that date, but extensive use of broad spectrum insecticides in the late 1940's resulted in upsurges of the pest on soybeans. Current programs are oriented at restoring the pre-existing natural balance.

Biology: _Aphis glycines_ uses _Rhamanus dauvuricus_ as the only wild host for overwintering. They overwinter as eggs. _Glycine max_ and _G. soja_ are the summer hosts. After colonization of soybeans, they feed on the stems and buds of the seedlings and young plants. Later in the season they move to the lower leaves; aphids at this stage are smaller and the populations decline. From late August on, they multiply rapidly until soybeans mature; then they migrate back to _Rhamanus_. They are up to 15 generations on soybeans and a total of 18 generations per year. Optimal developmental conditions are 22 to 25° C and less than 78 percent R.H. Aphid outbreaks seem to be more serious in drier years. Experiment have con- firmed the ability of the soybean aphids to transmit SMV. There is, however, no study on the relative importance of soybean colonizing species, as opposed to transient species, as vectors of SMV.

Biological control: Biocontrol of aphids is based on the preservation of natural enemies. Surveys conducted in Liaoning Province showed 42 species of aphid natural enemies, in 21 genera, 8 families, and 5 orders. (See Appendix 1 for list of most important species.) In Liaoning Province, research has concentrated on the coccinellid, _Harmonia_ (_Leis_) _axyridis_.

This predator moves from early spring crops to soybeans, then to sorghum, and finally to corn before migrating to overwinteringsites on mountain slopes. Overwintered beetles are attracted to flowers of apricot in the spring, and then colonize spring crops. Other important aphid predators are _Propilea japonica_ and _Adoni variegata_. _Aphidius longipetiolus_ and _Trioxys_ spp. are the main parasites.

Cultural control: No specific cultural control methods have been investigated, but it is conceivable that control of _Rhamnus_ may deprive the aphids of their overwintering hosts. When soybean is intercropped with sorghum, predators are first attracted to soybeans and fed on the soybean aphids. Later they migrate to sorghum where they feed on _Aphis saccharum_. It seems that both crops benefit from the interaction.

Host plant resistance: Screening for resistance is considered in the Heilongjiang and Jilin provincial programs, but there has been no reference to sources of resistance. The released variety 'Tiefeng 18' from Tieling District Agricultural Research Institute seems to be more tolerant to aphids, recovering after attack subsides.

Chemical control: Rogor (dimethoate) is the standard insecticide for aphid control. At Tieling, experiments with strip treatments for preservation of predators while controlling the aphids, have been conducted and results seem to be encouraging.

Integrated control: The program is based mostly on the preservation of natural enemies with the selective use of insecticides. In this case selectivity is achieved by using a

formulation of Rogor in sand which apparently is less distruptive of the natural enemy complex than either sprays or dusts. Other insecticides used are Sumithion and malathion. In Jinan we were told that control of aphids by chemicals early in the season builds up populations of natural enemies.

We did not receive a clear indication of current economic injury levels for aphids.

Other Pests

Heliothis dypsacea: This species has two generations a year in Liaoning Province. The first generation occurs in the middle of June and it is the most damaging. The second generation occurs late in July or early in August. They also attack red beans, but do not feed on sorghum.

Ascotis selenaria: Occurs in outbreak numbers in isolated areas of Liaoning Province but does not require control measures.

Plusiinae: There are several species of plusiines but none seems to reach outbreak numbers.

Hedilepta indicata (soybean leafroller): Has two generations per year. The first generation is more damaging, particularly when there is excessive rainfall in July and August.

Tetranychus cibarinus: The spider mites are sporadic and spotty, becoming particularly serious during dry years, as is also the case in the United States.

[illegible] [illegible] [illegible] supplement [illegible]

[illegible] natural enemy complex than [illegible] species [illegible] the sap-feeding and defoliating [illegible] no hold them control in check by chemicals [illegible] reason [illegible] up [illegible] natural control. We do not [illegible] a real [illegible] as control [illegible]

Other Pests

Heliothis (armigera): This species has two generations a year in [illegible]. The first generation occurs in the middle of June and is in the most [illegible]. The second generation occurs late in [illegible] or [illegible] in [illegible]. [illegible] also attack [illegible], but do not feed or emerge.

[illegible] [illegible]: Occurs in [illegible] numbers in isolated areas of [illegible] Provinces but does not require control measures.

Plantbugs: There are several species of plantbugs that are known to [illegible] each [illegible] important.

[illegible] [illegible] (common [illegible]): The [illegible] generations per year. The first generation is more abundant. [illegible] 1947, [illegible] abundance [illegible] and [illegible]

[illegible] [illegible]: The [illegible] of the [illegible] species [illegible]

[illegible] [illegible] years [illegible]

[illegible]

Ophyomyia phaseoli: In Shandong Province, the bean fly has five generations per year (three in soybean fields). The pupae overwinter in stems of corn and sorghum. Control is directed againt the second generation using Sumithion, Phoxin, malathion, or Rogor.

White grubs: *Holotrichia obliqua* has one generation every 2 years; *H. morosa* and *Anomala* (*corpulenta*)? have one generation per year. Grubs are controlled by soil applications of granular Phoxin or Furadan or dusting parathion and parathion + BHC. Adults are also controlled in the Shandong Province by spraying willow and poplar trees, which are used as food by the beetles.

OBSERVATIONS ON INSECT PEST AND NATURAL ENEMIES

Observations that we made in soybean fields in the provinces of Hebei, Heilongjian, Jilin, Liaoning, and Shandong gave us first-hand indication of some of the prevalent pest species and their natural enemies. The beat cloth method was used to assess pests and predators and to collect lepidopterous larvae which were held on diet for parasite emergence or disease development. Stink bug egg masses were collected by plant examination.

Although pest problems consisted primarily of aphids (*Aphis glycines*) and the soybean pod borer (*Leguminivora glycinivorella*), the latter was not very abundant. There was an absence of problems from defoliators or pod consumers such as *Heliothis*, with the exception of Shandong Province, where

Sylepta ruralis and *Plusia* sp. were more abundant. Local entomologists indicated that economic problems with defoliators did occur in Shangong. Although foliage damage was minor and pod feeding was not observed, the chrysomelid beetle, *Monolepta nigrobilineata*, that has a biology similar to that of *Cerotoma trifurcata*, did occur in all areas. It appeared to be more abundant in the Northeast. In one field in Liaoning, a moderate population of grasshoppers, probably *Atractomorpha bedeli*, was observed.

The stink bug, *Dolycoris baccharum*, was found in all areas, and populations as high as 15 to 18 per meter of row (about 60-cm rows) were observed in plantings of different lines and varieties at an experimental station in Liaoning Province. Economic losses were estimated to exceed 30 percent in yield alone, without consideration of seed quality. We recommended that a survey of the province be conducted to determine populations of stink bugs.

Although an occasional lepidopterous larva was observed to have died from a disease that appeared to be *Nomuraea*, diseases did not generally seem to be important.

Predators were observed to be quite important in most fields visited. In the Northwest, green lacewings and lady beetles were very abundant. There were also significant numbers of nabids, spiders, and *Orius*. In Liaoning and Shandong Provinces, spiders and nabids appeared to be much more abundant and green lacewings and lady beetles were less abundant. Also, a predaceous ground beetle was observed

searching foliage in the south and feeding on an occasional aphid. Not a single geocorid was observed.

Preliminary information indicates that parasites are very important in regulating lepidopterous larvae (*S. ruralis* and *Plusia*) as well as stink bugs. Apparently four or five different parasitic wasps and one parasitic nematode was recovered from lepidopterous larvae. Also two or three parasitic species (probably *Trissolcus* sp. and an unknown species) emerged from stink bug egg masses and a parasite similar to *Trichopoda* was observed and photographed in association with stink bugs. Many of the larvae held for parasitism died because of poor rearing conditions -- they were held in plastic bags, often for long periods of time before being placed on diet. More complete identification of parasites will be available later.

LIST OF SOYBEAN INSECT PESTS AND THEIR NATURAL ENEMIES
AS PROVIDED BY ENTOMOLOGISTS IN VARIOUS PROVINCES
AND FROM THE LITERATURE OBTAINED*

Pests	Natural enemies	Provinces reporting
Lepidoptera		
Tortricidae		
Legumunivora glycinivorella	Pristomerus chinensis	Heilongjiang, Jilin
	Phaneroloma planifrons	Liaoning, Shandong
	Nemertidae - gen. sp.	
Matsumuraese phaseoli		
Noctuidae		
Heliothis dipsacea		
Heliothis armigera		
Heliothis assulta		
Agrotis tokionis		
Agrotis ypsilon		
Bomolocha tristalis		
Cauninda archesia		
Euxoa oberthuri		
Euxoa segetum		
Hypena rostralis		
Hypena taenialoides		
Ilattia octo	Charops bicolor	Shandong
Plusia agnata	Iitomastis maculata	Shandong
	Microgaster sp.	
	Charops bicolor	

*Generic names have been changed to currently accepted names whenever possible; most scientific names, however, have been transcribed as received from Chinese researchers.

Pests	Natural enemies	Provinces reporting
Plusia nigrisigna		
Prodenia litura		
Arctiidae		
Spilosoma		
lubricipeda		
Spilosoma subcarnea		
Amsacta lactinea		
Limantryidae		
Cifuna locuples	Teleomus dalmani	
Orgyia antigua		
Gelechiidae		
Stomopteryx		
subsecivella		
Pyralidae		
Etiella	Chelonus munakatae	Shandong
zinckenella	Tetramorium guinense	
Loxostege		
sticticalis		
Loxostege		
verticalis		
Hedilepta indicata		
Maruca testulalis		
Geometridae		
Ascotis selenaria		
dianeria		
Lygaeidae		
Chauliops fallax		

Pests	Natural enemies	Provinces reporting
Homoptera		
Aphididae		
Aphis glycines	*Chrysopa sinica*	Shandong, Liaoning
Aphis craccivora	*Chrysopa phyllochroma*	
Myzus persicae		
Macrosiphum pisi	*Chrysopa septempunctata*	
Macrosiphum pisi	*Chrysopa formosa*	
	Coccinella septempunctata	
	Propylaea japonica	
	Leis axyridia	
	Hippodamia tredecimpunctata	
	Adalia bipunctata	
	Oeraocoris punctulatus	
	Nabis sinoferus	
	Orius minutus	
	Paragus quadrifasciatus	
	Syrphus corollae	
	Epistrophe baltata	
	Aphidius longipetiolus	Liaoning
	Trioxys glycines	
	Scimnus babai	
	Scimnus hoffmani	
	Orius saureri	
Meloidae		
Epicauta gorhami		Jilin
Epicauta chinensis		
Epicauta xantusi		
Mylabris phaberata		
Mylabris cichorii		
Lytta caraganae		
Meloe auriculata		

Pests	Natural enemies	Provinces reporting
Scarabaeidae		
<u>Holotrichia diomphalia</u>		
<u>Holotrichia morosa</u>		
<u>Holotrichia titanis</u>		
<u>Anomala exoleta</u>		
<u>Anomala corpulenta</u>		
<u>Anomala mongolica</u>		
<u>Pentodon patruelie</u>		
<u>Serica orientalis</u>		
Tenebrionidae		
<u>Opatrum subaratum</u>		
Hemiptera		
Pentatomidae		
<u>Dolycoris baccharum</u>		
<u>Eysacoris guttiger</u>		
Miridae		
<u>Lygus lucorum</u>		
<u>Adeiphocoris suturalis</u>		
<u>Adeiphocoris</u> Lineolatus		
<u>Acyrtosiphon pisi</u>		
<u>Aulacortum solani</u>		
<u>Aphis laburni</u>		

Pests	Natural enemies	Provinces reporting
Diptera		
Agromyzidae		
Ophyomia phaseoli		
Ophyomia shibatsuji		
Melanagromyza sojae	Gronotoma sp.	Shandong
	Cyrtogaster sp.	
	Pleurotropis sp.	
Japanagromyza tristela		
Orthoptera		
Acrididae		
Atractomorpha sp.		Hopei, Shandong

APPENDIX 2

OBSERVATIONS ON PARASITE EMERGENCE AND DISEASE DEVELOPMENT FROM STINK BUG EGG MASSES AND LEPIDOPTEROUS LARVAE COLLECTED FROM SOYBEAN IN THE PEOPLE'S REPUBLIC OF CHINA, WITH NOTES ON PREDATOR COMPLEXES

Province	Date	Insect Hosts	Parasites/Diseases Recovered*	Predominant Predators
Heilongjiang	8-14	Unspecified stink bug egg masses + _Sylepta_ sp.	Wasps from 5 egg masses	Green lacewings, coccinellids, spiders, and nabids
Heilongjiang	8-15	26 _Sylepta_ sp., 2 Pentatomid egg masses	1 parasitic wasp from _Sylepta_ sp.	"
Jilin	8-18	1 _Sylepta_ sp.		"

Province	Date	Insect Hosts	Parasites/Diseases Recovered*	Predominant Predators
Jilin	8-20	43 _Sylepta_ sp. 5 _Heliothis_ sp. 2 _Ascotis_ sp.	2 medium-sized wasps; 4 small wasps	"
Jilin	8-23	75 _Sylepta_ sp. 2 _Heliothis_ sp.	6 medium-sized wasps (apparently similar); 1 different wasp	"
Liaoning	8-25	8 _Sylepta_ sp. 6 _Cyrphis_ sp. 1 _Plusia_ sp. 4 _Heliothis_ sp. 7 _Ascotis_ sp. 3 Pentatomid egg masses	3 medium-sized wasps (all apparently different species), 1 nematode parasite, 2 _Nomuraea_ cadavers	Spiders very high + green lacewings, nabids, and lady beetles
		Several wasp pupae in one group (possibly a gregarious _Apanteles_ host unknown	Several adults emerged	

Province	Date	Insect Hosts	Parasites/Diseases Recovered*	Predominant Predators
Liaoning	8-27	12 Sylepta sp. and/or Plusia sp. 2 Etiella sp. 27 Pentatomid egg masses	1 medium-sized wasp 1 Nomuraea 1 wasp 7 wasps (apparently 3 different species)	Spiders very high + green lacewings, nabids, and lady beetles
Liaoning	8-26	Unspecified lepidopterous larvae	1 parasitic wasp	"
Shandong	8-30	39 Sylepta sp. and/or Plusia sp. 2 Plusia pupae 2 Heliothis 2 Pentatomid egg masses	**	Spoiders and cocinnellids very abundant; 1 carabi predator (medium-sized); few green lacewings
Shandong	8-30	9 Plusia sp. 15 Sylepta sp.	**	"
Shadong	8-31	87 Sylepta sp.	**	"

*From two to four typical _Nomuraea_, cadavers were recovered. No other entomopathogens were positively identified or recovered, although suspects were observed. No parasites have been positively identified. However, attempts are being made in Stoneville, Mississippi, to culture three egg parasites of pentatomids. F_1's have been recovered from _Euschistus servus_ eggs of one species (probably _Trissolcus_) and two apparently different species (another _Trissolcus_ and _Telenomous_) were observed stinging _Euchistis_ eggs. Although from five to eight different parasites of lepidopterous larvae were recovered, none were imported alive in sufficient numbers to attempt culture.

**Data incomplete; however, many larval deaths due to holding larvae too long in plastic bags and/or poor diet preparation. A few parasites apparently emerged in quarantine at Stoneville, Mississippi.

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